INDUSTRIAL DIAMOND REVIEW

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Generally Speaking

Another ' Biggest '

This time a metal-cutting circular saw, designed for cutting very large sheets of aluminium alloy. The saw carriage has an overall travel of 96 feet, and the sheets that can be dealt with are up to 57 feet long by 10 feet wide, and may be as much as six inches thick. The saws themselves* are fifty inches in diameter, with tungsten carbide tipped teeth at 4 inch pitch. To obviate the risk of damage to the saw and to the workpiece at the very high peripheral speeds (13,500 ft/min) and rates of feed (180 in./min) the highest degree of accuracy in their manufacture is necessary, and in fact the final process is diamond-grinding the top of each tooth to a radial accuracy of ±0.001 inch.

The Highest Finish ?

It has already been proved that it is not so difficult to get high altitude rockets and space vehicles away, as to get them back safely, and at present there is a good deal of experimental work going on on these lines. The principal, although not the sole, problem is that of heat on re-entry into the earth's atmosphere, and this is being very thoroughly investigated.

Many of the experimental vehicles are being fitted with nose caps of Inconel, a nickel alloy that can stand up to the heats reached during flight at hypersonic speeds (speeds as great as ten times that of sound have been reached by some of these rockets). These nose caps, spun out of sheet metal, are carefully polished with successive abrasive papers of finer and finer grit. The last stage of finishing, to give the cones a finish of optical quality, eliminating even the smallest roughness that might cause sufficient friction to bring about dangerous overheating, is hand-lapping with diamond compound. It has been found by experience that this is the only way in which the required degree of finish can be obtained.

ADAMANT

* Made by Spear and Jackson Ltd., Sheffield

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In-Plant 'Diamond Mines' Are Expensive . . . . . Spot Yours and Save

by Carol E. Reuss

Concluded from p 130, *July.*

The fact that GEC is successfully producing man-made diamonds in its pilot plant in Detroit does not mean that the need to conserve diamonds has lessened. The man-made diamonds, slightly more expensive than natural diamonds, will augment the present and future supply of natural diamonds. They will help to make it possible to extend the uses of diamonds to ceramics, high temperature alloys, and other yet unforeseen manufacturing and grinding tasks. Then, too, in case world situations cause the supply of natural diamonds to be cut off, man-mades will help to fill the gap.

What are they like? So far man-made diamonds are available in very fine sizes only. So fine, in fact, that the largest is about the size of a coarse grain of sand. Uses include grinding wheels, lapping compounds, and truing tools which utilize small diamond particles.

The human side

People can make or break a diamond conservation programme, just as they can make or break the company's darts club. It takes a continuing campaign—brain-washing, if you will—to make and keep the shop people, the real diamond and carbide users, conservation and economy conscious. Training them to use their machines and tools is just one part of the answer; the other involves the use of strictly human-to-human techniques.

Impress upon the tool grinders, for example, the actual dollar-and-cents value of the diamond wheels they are using. Show the carbide tool user how much more it costs if a tool is run beyond the simple regrind point, thus necessitating a major grinding job rather than a touch-up grind. Let the abrasive wheel user see how much damage, dollar-wise, results from not turning a truing tool . . . from plunging a hot diamond into coolant.

Cater to the worker's sense of ownership, Ripple suggests, by assigning a specific diamond wheel to each tool grinder. This means an increased initial expense, but Carborundum records show that the sense of ownership and care usually results in a considerable drop in wheel expense. Instil in the shopmen the interest in spotting wear or trouble spots before they become serious problems.

Call on suppliers to present instruction programmes or 'refresher' courses on tool and wheel use. A surprising amount of enthusiasm can by generated by such presentations or by distribution of supplier-prepared bulletins. Koebel Diamond Tool Company's booklet on wheel dressing and truing, 'For Men Only', is just one example of good supplier-inspired material specially prepared for the shop people. Wheel Trueing Tool Company's colour-slide lecture on the same subject is another.

On the negative side of the situation, do not let untrained employees dress or use diamond wheels. Make certain they are thoroughly trained before setting them loose. Hand pick your carbide tool grinders, for seldom do good production grinders become good tool grinders. Look for the steady, easy-does-it type worker when picking carbide tool grinders, not hurry-up production hands. It will pay in the long run.

Hold tool still . . . let wheel oscillate

For some time, carbide tool manufacturers have used oscillating grinders to mass-produce their diamond tools. Now, oscillating tool grinders, built on a tool-at-a-time instead of a 'gang' or mass production principle, are available for precision grinding of standard or special single-point tools. With these, all lateral movement of the tool on the part of the grinder-hand is eliminated. Instead, the tool is held in a fixed position, and the diamond wheel does the moving across the tool tip. The contact point of the wheel changes constantly, and generates a multiple cross-hatch pattern which is essential for very fine finishes.

The oscillating grinding action maintains a uniform flatness of the wheel face, as the entire wheel face reciprocates across the tool tip. This eliminates wheel grooving, and thus eliminates downtime for wheel truing and dressing. Only slight pressure on the work table is necessary for feeding the tool to the wheel.

The Hammond oscillating grinder can be combined with an electrolytic Power Pack for even faster electrolytic grinding. With both the Hammond and Wesson grinders, the operator can control the oscillation range.

There may be changes . . .

. . . in the diamond wheel identification system. Under consideration by US manufacturers is the feasibility of adding standard numbers to the present standard designations, to cover location of diamond section and wheel shape.

Easy dry salvage

Connect a disposable paper vacuum cleaner bag to the exhaust system connected to the grinding machine using diamond wheels and no coolant. When the bag is full, send it to the reclaimer, and attach another bag.

Compare reclaiming results . . .

. . . by sending sample batches of sludge or swarf to different reclaimers. For a true picture of the results from the different reclaiming methods, it is important to:

Send sludge or swarf from the same type, size, and brand of wheel, and from the same type operation, to each reclaimer.
Send like amounts of sludge or swarf.
Compare carat return from the different techniques, and choose your reclaimer accordingly.

Fine mesh . . . fine finish

Fine mesh (usually 220-230) diamond wheels give finer finishes to carbides. This was taken at more than face value at Black & Decker Manufacturing Company's Hampstead, Md, plant, with these favourable results: laboratory tests on single point tools, finish ground with a 1500S mesh wheel, showed that they lasted 4, 5, and in some cases, 10 times as long as tools sharpened by previously used methods. A five to seven micro-inch finish was obtained with the fine mesh wheels; previously a 15 micro-inch finish was obtained. The fact that the tools are used to machine die cast aluminium accounts for some, not all, of the improved tool life.

Cool . . . and re-loadable

Keep the carbide tool cool, and yet avoid having coolant sloshing over it during the grinding operation. This problem is solved with the Diamond Tool Company's through-wheel coolant system, built into its Coolie Grinder-Lap grinding machine. On one spindle is a 6 in., 60 mesh vitrified ceramic wheel; on the other, a permanently mounted, cast iron, reloadable lapping wheel. Both feature the through-wheel cooling. Coolant is gravity fed from a 6 oz sight feed oiler to a specially grooved wheel back. Centrifugal force pushes it through the wheel to its surface, and rapid evaporation does the actual cooling. A flood of coolant can be emitted, if desired. Tests show that the through-wheel coolant applicator can lower grinding temperatures by as much as 20 deg C.

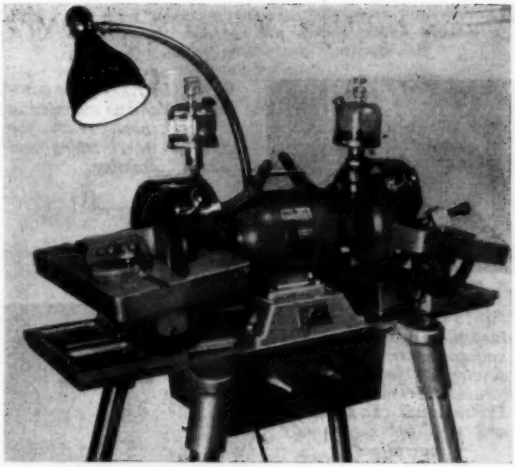

Fig 13. A vitrified ceramic wheel at one end and a cast iron reloadable lapping wheel at the other, both incorporating through-wheel cooling, are features of the Diamond Tool Company's Coolie Grinder-Lap grinding machine.

One of the units was set up at the US Metal Show, and was used to sharpen carbide and ceramic tools for other exhibitors. The diamond-loaded lapping wheel was kept ready for use by an occasional 10% diamond paste charge set into the wheel with a Roll-a-Set tool, which pushes new diamonds from the paste into the wheel, and re-sets dulled diamonds in the wheel. Four diamond wheels, loaded with four varied mesh sizes, were in constant use at the Show, and the total diamond consumption in paste was less than 4 carats, reports Sheldon Booth, President of The Diamond Tool Company.

The paste is a combination of fine and coarse mesh diamond and other abrasive. The coarser, not so hard grains, assist in re-setting the diamonds in the wheel surface, says Booth.

It takes up to 12 lb pressure to set the diamonds into the wheel; only 1 to 4 lb to sharpen even a ¾ in. tool. The process gives complete usage of 5-6 points of each diamond, and a 250-325 mesh diamond gives fast action and good average finish. Each re-loading/re-setting operation acts to true the wheel, and the machines, says Booth, hold a parallel indication of less than 0.0003 in.

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Abuse . Not Use . Wears Diamonds Most

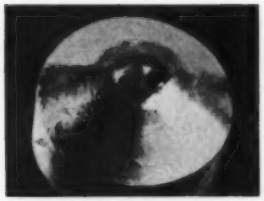


Fig 14 (*Left*). *A new octahedron diamond mounted in a steel shank ready for abrasive wheel truing and dressing.*

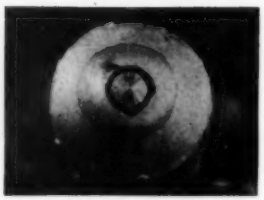


Fig 15 (*Right*). *A properly turned diamond tool has uniform sharp cutting ribs developed during use by turning the tool frequently. The diamond can be re-set and used for many more operations.*

Fig 16 (*Left*). *Feeding diamond truing tool straight into the wheel without drag angle fractures the diamond. A* 10°—15° *drag angle is recommended.*

Fig 17 (*Right*). *Side-swiping (feeding the diamond into the edge of the wheel each time it is turned) is another major abuse. Correct dressing should start at the highest point on the face of the wheel.*

Fig 18 (*Left*). *This abused tool was left in one position too long, so overheating and fracturing the diamond*

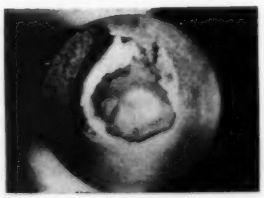


Fig 19 (*Right*). *Heat caused the material holding this diamond to melt. Such excessive heat has probably caused other damage as well.*

Photos by courtesy of the Wheel Trueing Tool Company.

Our thanks to these companies for supplying us with information for this feature:

AIT Diamond Tool Co.
Anocut Engineering Co.
Anton Smit & Co, Inc.
A. P. deSanno & Son Inc.
Bay State Abrasive Co.
Behr-Manning Co.
Buick Motor Div, GMC.
Carborundum Co.
Cincinnati Milling Machine Co.
Cratex Manufacturing Co.
Diamond Dust Co, Inc.
Diamond Tool Co.
Elgin Nat Watch Co, Abrasives Div.
Engis Equipment Co, Hyprez Div.
Elox Corp of Michigan.
General Electric Co, Metallurgical Products Dept.
Hammond Machinery Builders Inc.
Indusmond (Diamond Tools) Ltd.
Industrial Diamond Assoc of America, Inc.
Koebel Diamond Tool Co.
Mineral Research Lab.
Norton Co.
Ohio Metalworking Products Co.
Pure Carbonic Co, Div of Air Reduction Co, Inc.
Sheffield Corp.
Shelboerg Manufacturing Co.
Starlite Industries Inc.
Timken Roller Bearing Co.
Torit Manufacturing Co.
US Dept Commerce.
Wheel Trueing Tool Co.
Wickman Manufacturing Co.

Hicon Electro Diamond Tools

The application of the deposition process in causing diamond particles to adhere to a metal surface has for some time been used in the production of dental burrs and small grinding wheels, *ie* for internal grinders working on small internal diameters. In common with other firms, Triefus Industries, of Crawley, Sussex, have been working on this process, and have extended the range to cover much larger tools, including diamond grinding wheels with diameters up to 18 inches. The products are marketed under the name of 'Hicon'. The Triefus process, however, contains a number of innovations, particularly in the treatment of the diamond powder. The Company claims that these innovations result in a greatly increased efficiency in performance of the diamond.

Conventional types of impregnation cause a considerable amount of the diamond particles to be embedded in the metal of the tool or in an alloy matrix. By Hicon deposition, the diamond

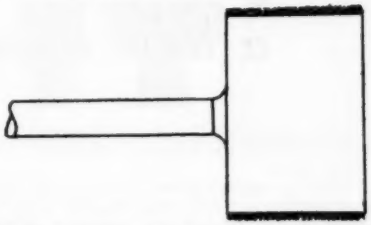
is deposited on the tool, as in Fig 1, thus presenting a larger cutting area of diamond for removing material in the cutting process. A commercial advantage is evident in the generally lower prices of the new type of tool in comparison with those formed by conventional impregnations. These advantages are incidental.

The main claim is that a number of common processes can now be carried out with a time saving of 50% and more. The Triefus product is already in use with leading manufacturers, who are employing it on tungsten carbide and extremely hard ceramics. In practically all cases Hicon tools are being used without coolants.

A relatively coarser finish is obtained with a given diamond mesh size in the new type of tool than is obtained with impregnated tools. This is due to the large protrusion of diamond particles, and has to be compensated for by a corresponding reduction in diamond size. A wide range of mesh sizes is available in the Triefus product: from coarse grits of up to BS 60 mesh to fine grits of 500 mesh. These sizes can be used on very complicated shapes required for difficult form grinding operations.

One of the most common applications of Hicon is the flared cup, taper cup, dish, and

Fig 1. Rough diagram to illustrate how the diamond particles are deposited on the tool, rather than being embedded in the tool material.



inverted dish type of wheel for tool and cutter grinding. Other standard products available in Hicon diamond tools include saw wires with a minimum thickness of 0.015 in., and cup and peripheral wheels with diameters up to 18 inches. The range also includes needle files, hand laps, and other small tools.

As we go to press it is announced that industrial diamonds and diamond tools are among the goods freed for export to the Soviet bloc and China as a result of revision of the strategic embargo list.

Diamond Powder Recovery with Heavy Liquids

By J. Swimmer

Concluded from p 138, *July*, 1958

For constant work with minus 15 micron powders, an angle head such as International No 812 (not illustrated) is required. It can go up to 3100 rpm using stainless 50 ml tubes. For still higher speed and improved separation of fine powders, the Servall[4] SS-34 centrifuge can operate up to 6,000 rev/min with eight 50 ml stainless tubes. Also it is directly adaptable to continuous work at this speed with their No KS-4 attachment.

For continuous centrifuging, a solid 8 in. diameter head shown in the top of Fig 4 is used. It has a solids working capacity between 1-2 lb/minute. In use the diamond-alumina mixture would collect in the head and the SC will overflow with MI into the draining chamber shown in the bottom of Fig 4. This head needs three equally spaced baffles added to it as it comes from the factory in order to bring the heavy liquids up to speed rapidly. A brass head can be used with MI but a stainless steel head is required for use with HI-GEE. The brass head must be drained and washed with acetone each night. This head has a cake capacity of 1.5 litres or about 11.5 pounds (over 25,000 carats) of diamond-alumina mixture.

Each of these three heads fits separately on the centrifuge shown in Fig 5. It is an International Equipment Co[5] Model CM. While this size centrifuge is normally found in clinical laboratories where it is a laboratory tool, it is a medium sized factory machine when used with MI and HI-GEE for diamond work. One machine for each head would be found in a well-equipped factory, and at least two would be required for an efficient medium size reclaiming operation. This eliminates the lost time in changing the heads back and forth for various operations. Yet a small laboratory may well get by with a four place 50 ml centrifuge costing under $200 complete.

4) Manufactured by Ivan Sorvall Inc, Norwalk, Conn, USA.

5) International Equipment Co, Boston 35, Mass, USA, represented in England by A. Gallenkamp & Co Ltd, 17-29 Sun Street, Finsbury Square, London EC2.

HABIT DIAMOND POLISHING MILL

a New approach to an ancient skill

In general principles the Habit Diamond Polishing Mill follows closely the methods proved by polishers from early times.

As a result of applying modern precision engineering to an ancient art and removing the shortcomings and faults of the conventional polishing bench it is now possible to use mechanical dops, jigs and fixtures, ensuring accuracy of angles and facets with complete certainty of results. Habit Diamond Tooling Limited are prepared to build such fixtures from drawings, sketches or rough ideas.

So accurate and interchangeable are the Mills that where more than one machine is installed dops may be passed from one Mill to another. This is especially valuable in gem polishing, where the cross polisher using a mechanical dop can pass work to the "brilliandeur," working on another bench, without removing the stone from the dop.

The heart of the polishing bench is the bearing, and in the design of the Habit Table this has received most careful attention, resulting in the evolution of a spindle which meets all the exacting requirements of the diamond polisher, who rightly demands complete freedom from vibration with a minimum of maintenance. You have only to listen to the Habit Mill in operation to appreciate the silk-smooth action.

The Habit Table is of heavy, solid construction to absorb vibration from internal and external sources and provide an absolutely flat working surface which will not warp or twist. It is carried on a strong tubular framework with adjustable legs which make special foundations unnecessary. In fact, there are no installation costs — just plug in to the electric supply and work can commence immediately.

Features of the Habit Polishing Bench include :

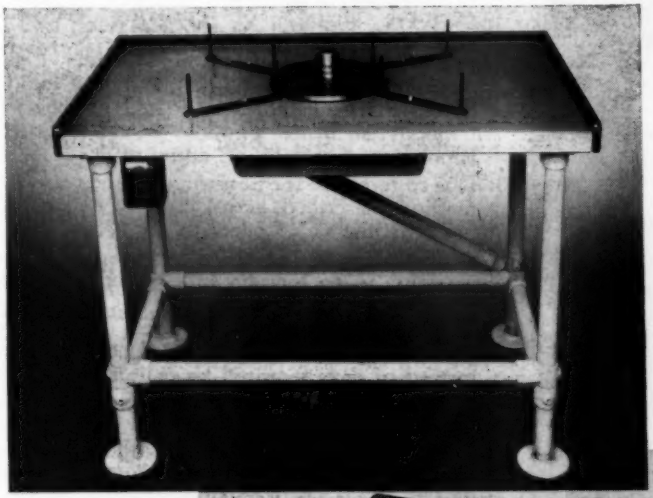
Economy of floor space, due to built-in drive unit.
Clear working area free of overhead obstruction.
Supplied with the internationally famous De Winter Scaife.
No balancing of scaife required.
Scaife always parallel to table within .002" (0.05 mm.)
Trouble free bearings, fully sealed against entry of dust, require lubrication only twice yearly.
Jointless long-life flat drive belt.
Complete freedom from vibration.
Absolute rigidity.
Dead flat table top enabling mechanical dops and simple or complex fixtures to be employed.
No corners or crevices to conceal dislodged diamonds.
Adjustable feet to accommodate uneven floors.
Easily dismantled for economical transport and shipping.
No installation costs—just plug in.

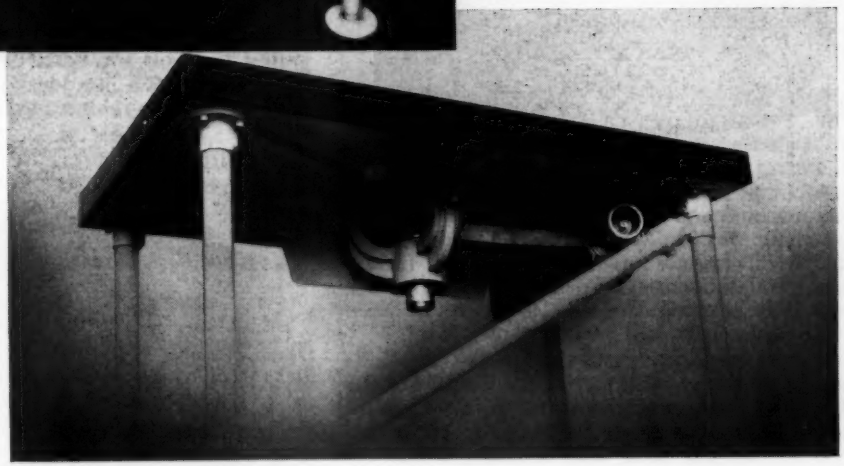
DIMENSIONS AND SPECIFICATIONS

Table area :	28" × 48" (711 mm. × 1219 mm.)
Height of table from floor :	36" (914 mm.)
Floor space required :	28" × 48" (711 mm. × 1219 mm.)
Electric motor :	1 H.P. 3 phase A.C. 1 phase A.C. or D.C. as specified.
Switchgear :	Push button overload trip type and isolator.
Scaife speed :	2,500 r.p.m.
Standard equipment :	1 De Winter Scaife. 4 Tang retaining stops. 1 spirit level. 1 scaive level gauge.

'HABIT'

'HABIT'





HABIT DIAMOND TOOLING LIMITED

294-296 LILLIE ROAD, FULHAM, LONDON, S.W.6.

Telephone No : FULHAM 7944.

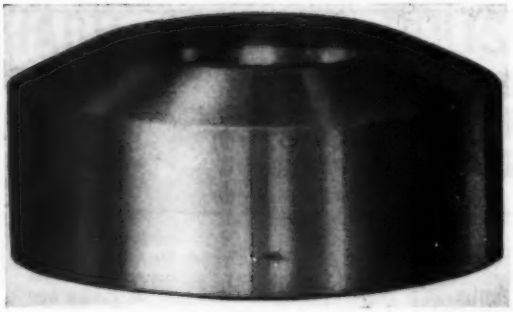


Fig 4 (*above*). *Solid* 8 *in. centrifuging head.*
(*below*). *Draining chamber for continuous centrifuging.*

A complete Model CM centrifuge set up with one machine and three heads can be purchased for about $1,000. This compares with $5,000-10,000 for furnace operations that will handle comparable quantities of material. A centrifuge with only nominal care will last up to 15 years while furnaces do well lasting up to 7 years.

It is important to note that since the liquids are clear to start with and at the finish, there is absolutely no diamond lost to them. Over-all loss of diamond in the heavy liquid process is zero to one per cent, and that 1% is still retrievable because it is not destroyed. Saving of diamond over other processes can also pay for the heavy liquids, and in time of shortage no price can pay for lost diamond. The over-all time consumed in the centrifuge operation is a matter of minutes using a centrifuge and heavy liquids. Unskilled operators can easily be trained to handle the operation. Diamond is not subjected to excessive temperatures and possible destruction. In furnace fusions over-all time consumed is of the order of days and the losses of diamond over and above that burned up and reduced in size depends on the skill of the operator. He handles diamond powders in quite large quantities of water to dissolve the fusion chemicals. This requires more skill and time than the centrifuge operations.

Summary:

1. Heavy liquids have been developed into a practical method of purifying diamond powders.
2. Silicon carbide and material lighter than diamond is floated off with methylene iodide of SG 3.3. Diamond is floated off heavier minerals such as alumina, metals, garnet, zircon, etc, with HI-GEE liquid of SG 3.55.
3. Due to re-use of the heavy liquids and recovery methods described, actual costs of material in use is as low as 5.5 cents/lb, or about $\frac{1}{3}$ that of chemicals for fusion methods.
4. Toxicity is as low or lower than alternate methods.
5. Over-all elapsed time required to purify diamond powders is reduced to minutes instead of days required by fusion methods.
6. Equipment costs are lower by a factor of 5-10 times.
7. Over-all losses of diamond to the liquids is zero, and actual losses of diamond run zero to 1%. This 1% is retrievable.
8. The diamond is in no way subjected to excessive destructive temperatures.

Fig 5. *International Equipment Company centrifuge.*

Blasthole Diamond Drilling at Flin Flon *

by T. A. O'Hara **

Diamond drills have been used for blasthole stoping at Flin Flon since 1941. No other stoping method could compete economically in Flin Flon's strong ore, and no other method of drilling blastholes can compare with diamond drilling in economy, speed, or flexibility.

The chief methods of blasthole stoping employed at Flin Flon do not differ appreciably from methods in use at other mines, but the high performance attained by diamond drills results in their use for an unusually wide range of blasthole stoping methods and development work.

The strong, fine-textured character of the Flin Flon ore is a major factor in low diamond costs, but rapid penetration is impossible by diamond drills or rock drills. High diamond drilling performance is attained by using equipment and methods that minimize drill 'downtime.'

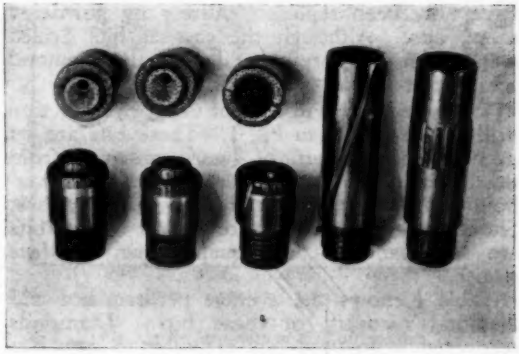


Fig 1. Diamond bits and shells used at Flin-Flon: (L to R) 200 series pilot bit, 50 series pilot bit, 50 series core bit, strip shell, and rib shell.

Diamond bits

EX diamond bits have been used for all production drilling since 1949. Prior to 1949, extensive tests using $1\frac{5}{8}$ and $2\frac{1}{8}$ in. bits did not show sufficient reduction in footage and breakage costs to warrant the additional cost of drilling larger-size holes.

Bits of the straight-wall coring and pilot-blast types are used. Core bits are used in hard quartz porphyry or in very soft chlorite schist where the pilot blast bit tends to mud up. Pilot blast bits are used chiefly in the solid sulphides which contain a high proportion of pyrite. Concave bits are not used because of their high diamond loss and their greater tendency to wander, although they usually drill at a slightly higher speed in medium sulphide ground.

Bits are set with diamonds running 50/ct or 200/carat. The 200 series bits drill at a faster rate than 50 series bits in hard ground, but in soft ground the 200 series bits tend to mud up easily because of the reduced sludge clearance of the smaller diamonds. In hard ground the diamond points on 50 series bits tend to polish and the drill may stall.

In general, bits set with small diamonds drill faster than bits set with large diamonds, but they mud up more frequently in soft ground and lose more diamonds. These features were emphasized in tests of 30 series and 300 series bits.

The bit matrix is powdered tungsten alloy which has a hardness of RC 20. This matrix is tough, holds diamonds well, and wears down fast enough to maintain adequate diamond exposure, without undermining the diamond support. In hard ground, however, matrix wear may be too slow to maintain sufficient diamond exposure for free cutting, and bits become 'metal bound.'

Bits set with a tungsten-carbide matrix are unsuitable for Flin Flon rock. This matrix has excellent diamond-holding properties and is resistant to erosion, but the bits become

Table I

Diamond recovery of bits and shells 1953/54

Type of bit or shell	Number used	Bit wt carats	Recovery carats	Carat loss/ 1,000 ft	Scrap carats	Footage/ bit
50 pilot bits	1,122	7.36	6.13	4.1	0.31	295 ft
50 core bits	907	5.22	3.39	8.7	0.35	210 ft
200 pilot bits	1,062	5.29	4.18	3.7	—	298 ft
200 core bits	41	2.98	1.68	10.6	—	123 ft
Strip shells	222	7.53	3.01	1.3	0.71	3,430 ft
Rib shells	25	12.28	5.78	1.5	2.09	4,190 ft

* Reprinted by permission from *Mining in Canada*, book published in 1957 by Northern Miner Press Ltd., Toronto, Canada, for visitors to the 6th Commonwealth Mining and Metallurgical Congress. Price of book in Great Britain: £4 6s 0d.

** Research and Ventilation Engineer, Hudson Bay Mining and Smelting Co. Ltd.

metal bound rapidly and drilling speed is reduced. These bits drill 22 per cent more slowly than bits set with a tungsten-alloy matrix. Cast-set bits with a bronze matrix were extensively used at Flin Flon during the war years, but these have now been replaced entirely by powdered metal bits. Although the cast-set bits drilled faster than powdered metal bits, the diamond loss in cast-set bits was much higher.

The types of bits in current use for production drilling are shown in Fig 1. These bits are set in the Truco pattern of sworls radiating from the bit centre to the bit periphery. The water-hole in the pilot blast bits has no sludge groove. Shoulder stones and centre stones on all bits are larger and of finer quality than the face stones.

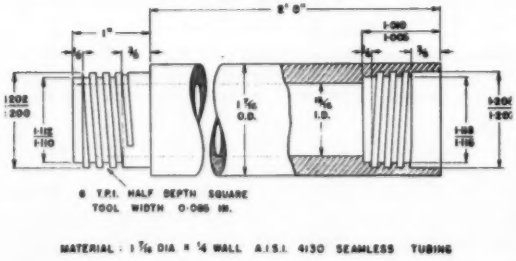
Table I shows the average performance and diamond recovery of these bits. Diamonds recovered from used bits are reset in new bits by the manufacturer. Sufficient new key stones are added to give adequate protection to the vulnerable points on the bit face. Diamond scrap recovered from bits is credited at $2.00/carat by the manufacturer.

Each driller's contract is charged with a proportion, usually about 25 per cent, of the full face value of the bits used. This proportion is based on the average diamond loss plus setting charge of all bits returned for resetting. This charge encourages the drillers to obtain the maximum economic footage from each bit used. Consequently, old bits are retained for collaring holes or for drilling in easily drilled ground, and metal bound bits are reserved for use in erosive ground. The bit charge does not penalize a driller for excessive diamond loss except as this loss affects the general average. Nevertheless, bits with excessive diamond loss are usually returned promptly because they drill more slowly than new bits.

Shells

A reaming shell is always used to decrease rod wear and to assist in stabilizing the bit. Fig 1 shows the two types of shell in general use. Strip shells are set with diamonds sized at 20 to 30/ct in four strips spaced around the shell periphery. These shells are used in hard and medium ground, but in fast drilling ground the large flow of sludge gouges the diamonds from the leading edges of each strip. Rib shells set with diamonds sized at 6 to 10/ct are used in this fast-drilling erosive ground. Shell recovery and performance is shown in Table I.

Fig 2. Diamond drill rod.



Drill rods

Drill rods are machined locally in 2 ft lengths from 1 7/16 in. outer diameter alloy steel tubing as shown in Fig 2. No couplings are used; rods are coupled directly through a male-female thread joint. The rods travel 5,260 ft of hole before being discarded. Ninety-five per cent of the rods are discarded because of wear which has caused failure or distortion of the female thread. Surface wear on rods averages 0.011 in./1,000 ft of hole travelled, and this wear is greatest at the female end of the rod which is worn to less than 1 5/16 in. diameter when the rod is discarded.

As each hole drilled requires a string of rods, the footage travelled by all rods is several times the hole footage. The footage of hole drilled/rod discarded averages 501 feet.

Formerly, 1,020 carbon steel tubing with a 7/32 in. wall was used for diamond drill rods, but rod wear and thread breakage was much greater than for the alloy steel tubing. The 7/32 in. wall carbon steel rods travelled 1,556 ft before being discarded, and surface wear averaged 0.024 in./1,000 ft travelled.

The advantages of the local rod design over the standard 1 5/16 in. diameter E rod are:

(*i*) The 7/16 in. diameter rod stabilizes the string of rods and permits little vibration in a 1½ in. diameter hole.

(*ii*) Although the 1 7/16 in. diameter rods are not heavier than standard E rods, they are much stiffer.

(*iii*) The male-female rod joint permits faster coupling and uncoupling.

(*iv*) Rods will accommodate the 7/8 in. core throughout the length of the rod string, and consequently less rod pulling is required when coring bits are used.

Diamond drills

The Longyear 3,420 diamond drill is used for almost all blasthole drilling. This drill is equipped with a six-bladed vane air motor developing 10 hp at 3,000 rev/min, a transmission with one forward and one reverse gear, and a

swivel head fitted with two feed gears giving feed rates of 375 and 700 revolutions/inch. Fig 3 shows the horsepower and torque of the motor at different speeds.

A distinctive feature of this drill is the hexagonal feed screw which is a notable improvement over the splined feed screw formerly used. The feed screw is driven at three-quarter motor speed by bevel gearing from the transmission. This drill is popular with the drillers because it is light in weight (152 lb) and easy to set up and operate, but its repair cost is high. Cursory tests of three other types of drill indicated no advantage that would justify a change.

Advantages of the 3,420 drill over 'in line' type drills are :

(*i*) The swivel head is only 14 in. long, hence the drill can be used in narrow drifts and raises.

(*ii*) Holes can be aligned more rapidly by swivelling the head than by swivelling on the arm dump.

(*iii*) Rotation, as well as feed direction, can be reversed; consequently rods can be uncoupled faster and jammed rods can be cleared more easily.

Disadvantages of the drill are:

(*i*) High repair cost, which has averaged 5.63 cents/ft drilled over the last 13 years.

(*ii*) High pitched sound of the vane air motor is objectionable.

(*iii*) Motor torque at low speeds is low, particularly if the operating air pressure is below 80 lb/sq inch. This is especially evident in hard ground when the drill may stall with the slow feed gear (700 rev/inch).

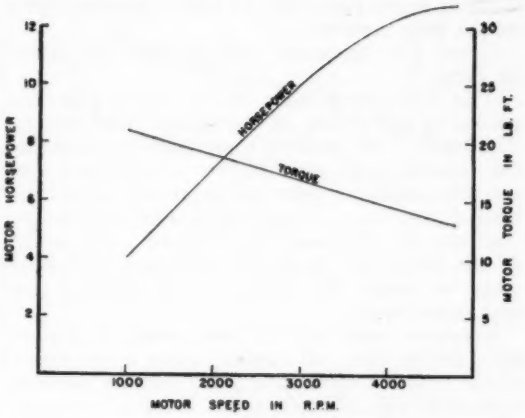


Fig 3. *Performance of drill air motor.*

Drill repairs

High repair costs result from the drill construction which has sacrificed ruggedness to attain light weight and flexibility of operation. Repair costs have been reduced somewhat by

Table II

Parts replacement on diamond drills

Part	Cost each ($)	Annual cost ($)	Number replaced/ 100,000 ft
Bevel gear	36.66	1,833.00	12.3
Bevel pinion	26.10	1,696.00	16.1
Feed screw	65.10	1,592.00	5.9
Feed nut	30.15	1,387.00	11.3
Feed shaft	25.53	1,327.00	12.8
Drive quill	26.65	884.00	7.9
Feed shaft gear	14.59	831.00	14.1
Swivel head bearings (greased)	(6 brgs)	1,211.00	79.1
Transmission bearings (oiled)	(5 brgs)	518.00	52.5
Rotor blades (6/rotor)	0.66	131.00	49.6
Shifter key	0.33	47.00	35.7
Shifter pinion	3.77	279.00	18.2

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bushing some parts and by stelliting other parts which wear rapidly.

Costs for frequent replacements are listed in Table II.

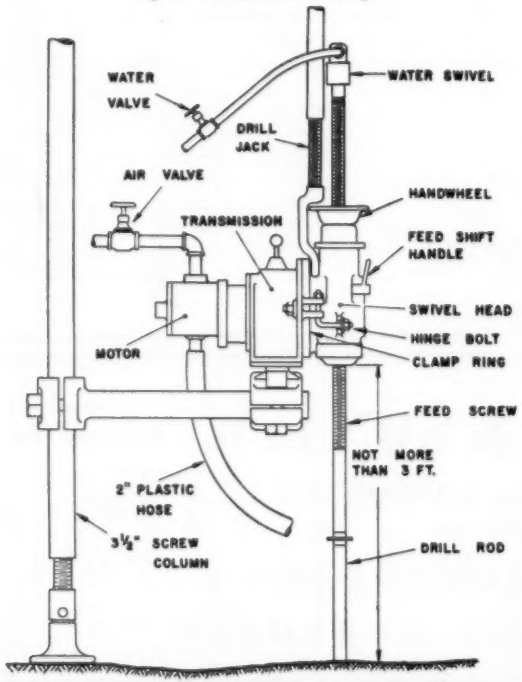
The high repair cost of the bevel gear and pinion is the result of the swivel head design. The method of meshing these gears by swinging the swivel head against the transmission inevitably leads to gear misalignment when the hinged parts wear. Gear and pinion replacement cost can be alleviated by frequent replacement of the hinge pin, hinge-pin bushings, and wear rings to retain the alignment of transmission and swivel head.

Excessive wear on the feed shaft, feed-shaft gear, shifter key, and shifter pinion is the result of the practice of shifting gears without slowing down the drill. This practice is difficult to curb among drill runners drilling on contract. Stelliting the keyway of the feed shaft has greatly increased its life. A stellited feed shaft lasts six times as long as the plain steel shaft furnished as a part replacement.

Rotor blades are frequently replaced, but because of their small cost, the annual cost of replacement is not high. The quality of the blades greatly affects their life. Some types of blades break off at the corners, and others split along the laminations; in either case, the rotor and cylinder liner is usually damaged. The quality of the compressed air supply greatly affects the wearing parts of the motor. Tarnishing of the rotor and cylinder liner, resulting in rapid wear of rotor blades, was observed when a well known brand of freezing preventative was used in the drill airlines. This freezing preventative, when analyzed, was found to contain a considerable quantity of water with dissolved acid salts, neither of which assists, in the prevention of freezing, and both of which will adversely affect rotating motor parts.

The service life of diamond drill bearings, especially greased bearings, is poor. Five brands of grease have been tried during the past four years, and the effectiveness of each brand was assessed according to bearing life obtained. Best results were obtained from a water-repellent lithium-base grease which has a worked penetration number of 315 and a melting point of 395 deg F (approx 217 deg C).

Fig 4. *Diamond drill set-up.*



Drilling practice

A typical drill setup is shown in Fig 4. No attempt is made to attain a narrow offset distance between the screw column and the hole to be drilled. Drill noise is reduced by piping the motor exhaust away from the drilling site.

Regulations require a two-man crew for each operating drill, although it is recognized that a greater footage per manshift could be attained by one man per drill, or by three men and two drills. Although the drill helper may not be continuously occupied, he can reduce the amount of drill downtime by preparing equipment for rod changes and hole changes, and by operating the drill during the drill runner's lunch period.

The time required for each drilling operation is shown in Table III. The footage drilled/shift, 161 ft as shown in this table, is typical of vertical ring drilling in open stopes with pilot-blast bits. Footage/shift is usually less than 100 ft when coring or when drilling vertical pillars, stope slots, and scram cones. The average footage drilled/shift for all diamond drilling operations in 1953 and 1954 was 131 feet.

Table III shows that five hours/shift are spent in drilling, hence the footage/shift is determined mainly by the drilling speed. Drilling speed varies with the type of bit, the air pressure, the type of ground, hole depth, and the footage drilled/bit. Typical drilling speeds in different types of ground are: 3½ in./min in quartz porphyry, 5 in./min in hard pyritic sulphide, 6½ in./min in medium sulphide, and 9 in./min in soft chlorite schist.

Contrary to popular belief, tests at Flin Flon show that drilling speed varies appreciably with hole depth, even in shallow holes. Fig 5 shows the results of drilling a series of 40 ft holes at 80 lb/sq in. air pressure. It is apparent from this figure that drilling speed is reduced as the hole is deepened, and that the reduction is most rapid in the shallowest part of the hole.

Drilling speed also varies with the footage drilled by the diamond bit. The drilling speed of a bit usually shows a slight increase after it is broken in during drilling of the first hole. Thereafter the drilling speed shows a slight decrease with each additional hole drilled, until the bit starts to lose diamonds and drilling speed declines sharply. Fig 6 shows the relationship between drilling speed and bit footage for the three bits used in the tests described below.

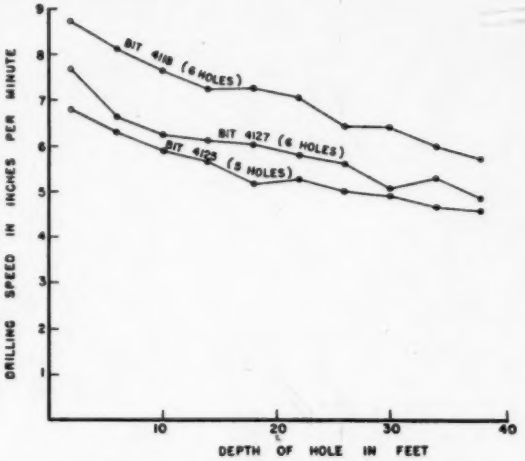


Fig 5. Drilling speed versus hole depth.

Drilling patterns

About 80 per cent of Flin Flon ore is recovered by diamond drilling methods. Diamond drills are used not only in stoping, but also in preparation for stoping, *ie* coning, undercutting, and cutting slots. Details of stoping methods at Flin Flon are described in two papers[1] prepared for the October, 1955, meeting of the Canadian Institute of Mining and Metallurgy, hence only a brief summary of diamond drilling patterns is given here.

Vertical rings of diamond drill holes are used in open stopes. Rings are drilled at 4 to 6 ft intervals, and holes in each ring are drilled with a maximum toe spacing of 12 feet. Holes are 40 to 70 ft long and are fanned from +10° to about −70°. This diamond drilling pattern accounts for most of the mine tonnage.

Vertical bench holes drilled from a crosscut in the centre of the open stope and blasted to a

1) Pillar Recovery at The Flin Flon Mine, by L. Ogryzlo. A. Stephansson, A. Johnson; Mining and Filling Flin Flon's Largest Open Stope, by L. Ogryzlo, F. Soltys, A. Johnson.

Table III

Time study of diamond drilling shift

Average of eight shifts drilling vertical rings in medium sulphide ore with EX pilot blast bits. Average air pressure 86 lb/sq inch.

Operation	Percentage 8 hrs (%)	Time/Shift (min)
Tear down and set up drill (every 2nd shift)	4	18.3
Re-align drill (3 holes—4.45 mins/hole)	3	13.4
Collar holes (4 holes—1.58 mins/hole)	1	6.3
Pull rods (4 holes—3.35 mins/hole)	3	13.4
Drill and rod trouble	1	5.8
Supervision	1	3.4
Rod changes (76.5 rods at 0.31 mins/rod)	5	23.8
Drilling (161 ft at 6.5 in./min)	63	304.3
Total time spent at working place	81	388.7
Nominal length of shift		480

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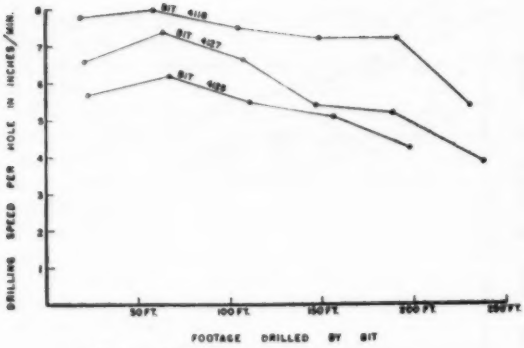


Fig 6. Drilling speed versus bit footage.

cut loose raise open the central stope slot. As the slot is opened up this spacing is increased to five feet. Holes are drilled from one sub-level to the next below, a vertical distance of 50 feet.

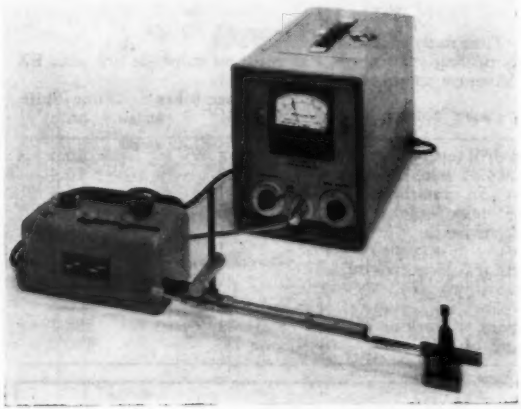
Horizontal rings are used in recovering horizontal pillars. These rings are spaced 4 to 6 ft apart, and holes in each ring are 40-80 ft long. Rings are drilled from 7 × 7 ft winzes sunk at the corners and sides of the horizontal pillar.

Combinations of these three drilling patterns are used for recovery of vertical pillars and ore remnants adjacent to mined-out areas.

To be concluded

Surface Finish Tester

The Profilometer Group III arrangement of a type QC amplimeter, type V mototrace, type LK tracer, and type BK linkarm, is shown below. The equipment gives arithmetical or rms readings, and has 6 ranges: 0-3, 10, 30, 100, 300, and 1,000 micro-inches. Tracing speed is 0.3 in./sec, with speedy reversals, over a length of trace of 1/16-2¾ inches. The single skidmount shown measures on internal diameters and outer diameters of ⅛ in., and can pass through a ¾ in. hole. Interchangeable skidmounts permit manual tracing.



US Distributor for Contour Rex

The Form-All Manufacturing Company, Long Valley, NJ, have appointed the American Coldset Corporation, Teterboro, NJ, as national distributors and exclusive sales agents for the Contour Rex wheel forming device. [See *Bibl Ind Diamond Appl* 1957 Vol 14 p B119 (July)].

'Di-X' Oriented Diamond Truing Tools

The Abrasive Dressing Tool Company, of Detroit, is now producing a new type of diamond truing tool manufactured under the name of Di-X. All diamonds used are positioned by x-ray orientation, and the manufacturers retain an x-ray film for each individual tool, showing that the diamond has been correctly oriented for its specific use. The x-ray orientation process is stated to increase diamond life by a factor of approximately ten.

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